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**ISOLATED NUCLEIC ACID MOLECULES ASSOCIATED WITH
COLON CANCER AND METHODS FOR DIAGNOSING AND
TREATING COLON CANCER**

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FIELD OF THE INVENTION

68 This invention relates to the isolation of genes associated with colon cancer, methods of diagnosing colon cancer using these, as well as other genes which are known, as well as therapeutic approaches to treating such conditions.

BACKGROUND AND PRIOR ART

5 It is fairly well established that many pathological conditions, such as infections, cancer, autoimmune disorders, etc., are characterized by the inappropriate expression of certain molecules. These molecules thus serve as "markers" for a particular pathological or abnormal condition. Apart from their use as diagnostic "targets", i.e., materials to be identified to diagnose these abnormal conditions, the molecules serve as reagents which can be used to generate diagnostic and/or therapeutic agents. A by no means limiting example of this is the use of cancer markers to produce antibodies specific to a particular marker. Yet another non-limiting example is the use of a peptide which complexes with an MHC molecule, to generate cytolytic T cells against abnormal cells.

15 Preparation of such materials, of course, presupposes a source of the reagents used to generate these. Purification from cells is one laborious, far from sure method of doing so. Another preferred method is the isolation of nucleic acid molecules which encode a particular marker, followed by the use of the isolated encoding molecule to express the desired molecule.

20 To date, two strategies have been employed for the detection of such antigens, in e.g., human tumors. These will be referred to as the genetic approach and the biochemical

approach. The genetic approach is exemplified by, e.g., dePlaen et al., Proc. Natl. Sci. USA 85: 2275 (1988), incorporated by reference. In this approach, several hundred pools of plasmids of a cDNA library obtained from a tumor are transfected into recipient cells, such as COS cells, or into antigen-negative variants of tumor cell lines. Transfectants are screened for the expression of tumor antigens via their ability to provoke reactions by anti-tumor cytolytic T cell clones. The biochemical approach, exemplified by, e.g., Mandelboim, et al., Nature 369: 69 (1994) incorporated by reference, is based on acidic elution of peptides which have bound to MHC-class I molecules of tumor cells, followed by reversed-phase high performance liquid chromatography (HPLC). Antigenic peptides are identified after they bind to empty MHC-class I molecules of mutant cell lines, defective in antigen processing, and induce specific reactions with cytolytic T-lymphocytes ("CTLs"). These reactions include induction of CTL proliferation, TNF release, and lysis of target cells, measurable in an MTT assay, or a ^{51}Cr release assay.

These two approaches to the molecular definition of antigens have the following disadvantages: first, they are enormously cumbersome, time-consuming and expensive; second, they depend on the establishment of CTLs with predefined specificity; and third, their relevance in vivo for the course of the pathology of disease in question has not been proven, as the respective CTLs can be obtained not only from patients with the respective disease, but also from healthy individuals, depending on their T cell repertoire.

The problems inherent to the two known approaches for the identification and molecular definition of antigens is best demonstrated by the fact that both methods have, so far, succeeded in defining only very few new antigens in human tumors. See, e.g., van der

Bruggen et al., Science 254: 1643-1647 (1991); Brichard et al., J. Exp. Med. 178: 489-495 (1993); Coulie, et al., J. Exp. Med. 180: 35-42 (1994); Kawakami, et al., Proc. Natl. Acad. Sci. USA 91: 3515-3519 (1994).

Further, the methodologies described rely on the availability of established, permanent cell lines of the cancer type under consideration. It is very difficult to establish cell lines from certain cancer types, as is shown by, e.g., Oettgen, et al., Immunol. Allerg. Clin. North. Am. 10: 607-637 (1990). It is also known that some epithelial cell type cancers are poorly susceptible to CTLs in vitro, precluding routine analysis. These problems have stimulated the art to develop additional methodologies for identifying cancer associated antigens.

One key methodology is described by Sahin, et al., Proc. Natl. Acad. Sci. USA 92: 11810-11913 (1995), incorporated by reference. Also, see U.S. Patent Applications Serial No. 08/580,980, and Application Serial No. 08/479,328, filed on June 7, 1995 and January 3, 1996, respectively. ^{5,698,396} ~~Both~~ All three of these references are incorporated by reference. To summarize, the method involves the expression of cDNA libraries in a prokaryotic host. (The libraries are secured from a tumor sample). The expressed libraries are then immunoscreened with absorbed and diluted sera, in order to detect those antigens which elicit high titer humoral responses. This methodology is known as the SEREX method ("Serological identification of antigens by Recombinant Expression Cloning"). The methodology has been employed to confirm expression of previously identified tumor associated antigens, as well as to detect new ones. See the above referenced patent applications and Sahin, et al., supra, as well as Crew, et al., EMBO J 144: 2333-2340

(1995).

The SEREX methodology has now been applied to colon cancer samples. Several nucleic acid molecules have been newly isolated and sequenced, and are now associated with stomach cancer. Further, a pattern of expression involving these, as well as previously isolated genes has been found to be associated with colon cancer. These results are the subject of this application, which is elaborated upon in the disclosure which follows.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Example 1

Tumor samples were obtained as surgical samples, and were frozen at -80°C until ready for use.

Total RNA was then isolated from the samples, using the well known guanidium thiocyanate method of Chirgwin, et al., Biochemistry 18: 5294-5299 (1979), incorporated by reference. The thus obtained total RNA was then purified to isolate all poly A⁺ RNA, using commercially available products designed for this purpose.

The poly A⁺ RNA was then converted into cDNA, and ligated into λZAP, a well known expression vector.

Three cDNA libraries were constructed in this way, using colorectal carcinoma samples. A fourth library, also from colorectal carcinoma, was prepared, albeit in a different way. The reasons for this difference will be clear in the examples, infra.

The fourth library was an IgG subtraction library, prepared by using a subtraction partner, generated by PCR amplification of a cDNA clone which encoded an IgG molecule.

See, e.g., Ace et al, Endocrinology 134: 1305-1309 (1994), and incorporated by reference in its entirety.

This is done to eliminate any false, positive signals resulting from interaction of cDNA clones which encode IgG, with the IgG then interacting with the anti-human IgG used in the assay, as described infra. PCR product was biotinylated, and hybridized with denatured second strand cDNA, at 68°C for 18 hours. Biotinylated hybrid molecules were coupled to streptavidin, and then removed by phenol chloroform extraction. Any remaining cDNA was also ligated into λ ZAP. All libraries were amplified, prior to immunoscreening discussed infra.

Example 2

Immunoscreening was carried out, using sera obtained from patients undergoing routine diagnostic and therapeutic procedures. The sera were stored at -70°C prior to use. Upon thawing, the sera were diluted at 1:10 in Tris buffered saline (pH 7.5), and were then passed through Sepharose 4B columns. First, the sera were passed through columns which had E. coli Y1090 lysates coupled thereto, and then lysates from bacteriophage infected E. coli BNN97 lysates. Final serum dilutions were then prepared in 0.2% non-fat dried milk/Tris buffered saline.

The method of Sahin et al., Proc. Natl. Acad. Sci. USA 92: 11810-11813 (1995), ^{U.S. PATENT 5,698,396} and ~~allowed U.S. patent application Serial No. 08/479,328~~, both of which are incorporated by reference, was used, with some modifications. Specifically recombinant phage at a concentration of 4×10^3 phages per 15 cm plate (pfus), were amplified for six hours, after

which they were transferred to nitrocellulose membranes for 15 hours. Then, the membranes were blocked with 5% nonfat dried milk.

As an alternative to the IgG subtraction, discussed supra, membranes were prescreened in a 1:2000 dilution of peroxidase conjugated, Fc fragment specific goat anti-human IgG, for one hour, at room temperature. Color was developed using 3,3-diaminobenzidine tetrahydrochloride, which permitted scoring of IgG encoding clones.

Membranes were then incubated in 1:100 dilutions of autologous sera, which had been pretreated with the Sepharose 4B columns, as described supra. The filters were then incubated, in a 1:3000 dilution of alkaline phosphatase conjugated Fc fragment specific, goat anti-human IgG, for one hour, at room temperature. The indicator system 4-nitroblue tetrazolium chloride/5-bromo-4-chloro-3-indolyl-phosphate was then added, and color development assessed. Any positive clones were subcloned, and retested, except the time on the nitrocellulose membrane was reduced to three hours. A total of forty-eight positive clones were identified.

Analysis of probes for SEQ ID NOS: 1 and 2 confirmed their universal expression.

Example 3

Example 2 described work using autologous serum. The positive clones were then rescreened, using allogeneic serum, following the same method discussed supra, in example 2, except IgG prescreening was omitted. The allogeneic sera was obtained from sixteen normal blood donors, and twenty nine patients who had been diagnosed with colorectal cancer.

The analysis with the two types of serum revealed that fourteen reacted with a subset of sera from normal and cancer patients, twenty-eight only with autologous sera, and six with both allogeneic and autologous sera. Over 60% of the allogeneic serum samples tested reacted with at least one of these positive clones. About 20% reacted with two or more.

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Example 4

In view of the results described in example 3, further experiments were carried out using serum samples from patients with other forms of cancer, i.e., renal cancer (13 samples), lung cancer (23 samples), and breast cancer (10 samples). The results are set forth in Table I which follow:

Clone Number	Normal Sera	Colon Cancer	Renal Cancer	Lung Cancer	Breast Cancer
NY-Co-8	0/16	8/29	1/13	0/23	0/10
NY-Co-9	0/16	5/29	1/13	1/23	0/10
NY-Co-13	0/16	5/29	0/13	0/23	0/10
NY-Co-16	0/16	3/29	0/13	0/23	0/10
NY-Co-20	0/16	4/29	0/13	0/23	0/10
NY-Co-38	0/16	4/29	3/13	0/23	1/10

Example 5

Following the screening work described supra, the cDNA inserts were purified and sequenced, following standard methods.

Of the six clones which were identified as being reactive with autologous and allogeneic cancer serum, and not with normal serum, two were found to be identical to previously identified molecules. Four others were found to have little or no homology to known sequences. These are presented as SEQ ID NOS: 1-4. Of twenty seven allogeneic colon cancer serum samples tested, 67% reacted with at least one of these antigens.

Example 6

The expression pattern of mRNA corresponding to SEQ ID NOS: 1, 2 and 4, as well as other sequences identified via the preceding examples was determined. To do this, RT-PCR was carried out on a panel of RNA samples, taken from normal tissue. The panel contained RNA of lung, testis, small intestine, colon, breast, liver and placenta tissues. The RNA was purchased from a commercial source. RNA from a colon tumor sample was also included. All samples were set up for duplicate runs, so that genomic DNA contamination could be accounted for. In the controls, no reverse transcriptase was used.

Primers were designed which were specific for the cDNA, which would amplify 5'-fragments, from 300-400 base pairs in length. The PCR reactions were undertaken at an annealing temperature of 68°C. Where appropriate, 5' and 3'-RACE reactions were undertaken, using gene specific primers, and adapter primers, together with commercially available reagents. Specifically, SEQ ID NOS: 2 and 4 were tested using RACE. The

resulting products were subcloned into vector pCR 2.1, screening via PCR using internal primers, and then sequenced.

5 SEQ ID NOS: 1 and 2 were found to be amplified in all tissues tested. SEQ ID NO: 4 was found in colon tumor, colon metastasis, gastric cancer, renal cancer and colon cancer cell lines Colo 204 and HT29, as well as in normal colon, small intestine, brain, stomach, testis, pancreas, liver, lung, heart, fetal brain, mammary gland, bladder, adrenal gland tissues. It is was not found in normal uterine, skeletal muscle, peripheral blood lymphocytes, placental, spleen thymus, or esophagus tissue, nor in lung cancer.

10 The analysis also identified differential expression of a splice variant of SEQ ID NO: 4, i.e., SEQ ID NO: 5. When the two sequences were compared, it was found that SEQ ID NO: 4 encodes a putative protein of 652 amino acids, and molecular weight of 73,337 daltons. SEQ ID NO: 5, in contrast, lacks an internal 74 base pairs, corresponding to nucleotides 1307-1380 of SEQ ID NO: 4. The deletion results in formation of a stop codon at the splice function, and a putative protein of 404 amino acids, and molecular weight 45,839. The missing segment results in the putative protein lacking a PEST protein degradation sequence, thereby suggesting a longer half life for this protein.

15 In additional experiments, primers designed not to differentiate between SEQ ID NOS: 4 and 5 resulted in almost universal amplification (placenta being the only exception). In contrast, when primers specific for SEQ ID NO: 5 were used differences were seen in
20 normal pancreatic, liver, lung, heart, fetal breain, mammary gland, bladder, and adrenal gland tissue, where there was no expression of SEQ ID NO: 5 found.

Example 7

Northern blotting was also carried out for SEQ ID NOS: 1, 2, 4 and 5. To do this, the same commercially available RNA libraries discussed supra were used.

Samples (2 ug) of polyA⁺ RNA were analyzed from these samples, using random, ³²P labelled probes 300-360 nucleotides in length, obtained from PCR products. These probes were hybridized to the RNA, for 1.5 hours, at 68°C, followed by two washes at 0.1xSSC, 0.1% SDS, 68°C, for 30 minutes each time.

SEQ ID NOS: 1 and 2 were again found to be universally expressed.

Example 8

Further screening identified additional isoforms of SEQ ID NOS: 1 and 4. These are set forth as SEQ ID NOS: 6, 7 and 8. The isoform represented by SEQ ID NO: 6 is a naturally occurring splice variant of SEQ ID NO: 1, found in normal colon. SEQ ID NO: 7, which is an isoform of SEQ ID NO: 4, was found in brain tissue, primarily spinal chord and medulla. SEQ ID NO: 8, was found in normal kidney and in colon tumors, metastasized colon cancer, gastric cancer, and in colon cancer cell line Colo 205. It was not found in any normal tissue other than kidney.

The foregoing examples demonstrate several features of the invention. These include diagnostic methods for determining presence of transformed cells, such as colon cancer cells, in a sample. The sample may contain whole cells or it may be, e.g., a body fluid sample, or an effusion, etc., where the sample may contain cells, but generally will contain shed antigen. The experiments indicate that there is a family of proteins, expression of which is

associated with colon cancer. Hence, the invention involves, inter alia, detecting at least two of the proteins encoded by any of SEQ ID NOS: 1-5 wherein, presence of these is indicative of a pathology, such as colon cancer or other type of related condition. Exemplary of the type of diagnostic assays which can be carried out are immunoassays, amplification assays (e.g., PCR), or, what will be referred to herein as a "display array". "Display array" as used herein refers to a depiction of the protein profile of a given sample. Exemplary of such displays are 2-dimensional electrophoresis, banding patterns such as SDS-gels, and so forth. Thus, one aspect of the invention involves diagnosing colon cancer or a related condition by determining protein display of a sample, wherein a determination of at least one of the proteins, or expression of their genes, is indicative of colon cancer or a related condition. There are many ways to carry out these assays. For example, as indicated herein, antibodies to the proteins were found in patient samples. One can assay for these antibodies using, e.g., the methodology described herein, or by using a purified protein or proteins or antigenic fragment thereof, and so forth. One can also assay for the protein itself, using antibodies, which may be isolated from samples, or generated using the protein and standard techniques. These antibodies can then be labelled, if desired, and used in standard immunoassays. These antibodies or oligonucleotide probes/primers may also be used to examine biopsied tissue samples, e.g., to diagnose precancerous conditions, early stage cancers, and so forth.

Similarly, any and all nucleic acid hybridization systems can be used, including amplification assays, such as PCR, basic probe hybridization assays, and so forth. The antibodies, such as polyclonal antibodies, monoclonal antibodies, the hybridomas which

produce them, recombinantly produced antibodies, binding fragments of these, hybridization kits, DNA probes, and so forth, are all additional features of the invention.

Any of these assays can also be used in progression/regression studies. One can monitor the course of an abnormality such as colon cancer which involve expression of any one of the proteins, the expression of which is governed by the nucleic acid molecules SEQ ID NOS: 1-5, simply by monitoring levels of the protein, its expression, and so forth using any or all of the methods set forth supra.

As has been indicated supra, the isolated nucleic acid molecules which comprise the nucleotide sequences set forth in SEQ ID NOS: 1-5 are new, in that they have never been isolated before. These nucleic acid molecules may be used as a source to generate colon cancer specific proteins and peptides derived therefrom, and oligonucleotide probes which can themselves be used to detect expression of these genes. Hence, a further aspect of the invention is an isolated nucleic acid molecule which comprises any of the nucleotide sequences set forth in SEQ ID NOS: 1-5, or molecules whose complements hybridize to one or more of these nucleotide sequences, under stringent conditions, expression vectors comprising these molecules, operatively linked to promoters, cell lines and strains transformed or transfected with these, and so forth. "Stringent conditions", is used herein, refers to condition such as those specified in U.S. Patent No. 5,342,774, i.e., 18 hours of hybridization at 65°C, followed by four one hour washes at 2xSSC, 0.1% SDS, and a final wash at 0.2xSSC, more preferably 0.1xSSC, 0.1% SDS for 30 minutes, as well as alternate conditions which afford the same level of stringency, and more stringent conditions.

It should be clear that these methodologies may also be used to track the efficacy of a

therapeutic regime. Essentially, one can take a baseline value for the protein or proteins being tested, using any of the assays discussed supra, administer a given therapeutic, and then monitor levels of the protein or proteins thereafter, observing changes in protein levels as indicia of the efficacy of the regime.

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The identification of the proteins and nucleic acid molecules set forth herein as being implicated in pathological conditions such as colon cancer also suggests a number of therapeutic approaches to such conditions. The experiments set forth supra establish that antibodies are produced in response to expression of these proteins, suggesting their use as a vaccine. Hence, a further embodiment of the invention is the treatment of conditions which are characterized by expression of one or more of the subject proteins, via immunotherapeutic approaches. One of these approaches is the administration of an amount of one or more these proteins, or an immunogenic peptide derived therefrom in an amount sufficient to provoke or augment an immune response. The proteins or peptides may be combined with one or more of the known immune adjuvants, such as saponins GM-CSF interleukins, and so forth. If the peptides are too small to generate a sufficient antibody response, they can be coupled to the well known conjugates used to stimulate responses.

Similarly, the immunotherapeutic approaches include administering an amount of inhibiting antibodies sufficient to inhibit the protein or proteins. These antibodies may be, e.g., antibodies produced via any of the standard approaches elaborated upon supra.

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T cell responses may also be elicited by using peptides derived from the proteins which then complex, non-covalently, with MHC molecules, thereby stimulating proliferation of cytolytic T cells against any such complexes in the subject. It is to be noted that the T

cells may also be elicited in vitro, and then reperfused into the subject being treated.

Note that the generation of T cells and/or antibodies can also be accomplished by administering cells, preferably treated to be rendered non-proliferative, which present relevant T cell or B cell epitopes for response.

5 The therapeutic approaches may also include gene therapies, wherein an antisense molecule, preferably from 10 to 100 nucleotides in length, is administered to the subject either "neat" or in a carrier, such as a liposome, to facilitate incorporation into a cell, followed by inhibition of expression of the protein. Such antisense sequences may also be incorporated into appropriate vaccines, such as in viral vectors (e.g., Vaccinia), bacterial constructs, such as variants of the well known BCG vaccine, and so forth.

An additional DNA based therapeutic approach is the use of a vector which comprises one or more nucleotide sequences, preferably a plurality of these, each of which encodes an immunoreactive peptide derived from the expressed proteins. One can combine these peptides expressing sequences in all possible variations, such as one from each protein, several from one or more protein and one from each of the additional proteins, a plurality from some and none from others, and so forth.

Other features of the invention will be clear to the skilled artisan, and need not be repeated here.

20 The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions

thereof, it being recognized that various modifications are possible within the scope of the invention.

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